adequate spring flows for riparian vegetation establishment, simulate effects of natural floods in scouring riverbeds and creating point bars, and increase the frequency and duration of overflow onto adjacent floodplains. In some cases, downstream infrastructure of river floodways may require upgrading to safely accommodate a more desirable natural variability and peak discharge magnitude associated with moderate floodflows (e.g., strengthen or set levees back) (Strategic Plan 2000).

Remove barriers to anadromous fish migration where feasible. Significant progress has been made in recent years to improve salmon passage on several spawning streams (e.g., Butte Creek, Battle Creek) by removing barriers, consolidating diversion weirs, or constructing state-of-the-art fish passage structures. Existing and potential spawning areas in the ERP focus area that are not obstructed by major reservoir dams, but are currently obstructed by other barriers, should be identified and action taken to restore anadromous fish spawning upstream (Strategic Plan 2000).

VISION

The vision for dams and other structures is to reduce their adverse effects by improving fish passage and enhancing downstream fish habitat.

Reducing these adverse effects will assist in the recovery of State- and federally listed fish species and contribute to sustainable sport and commercial fisheries.

To accomplish this vision, the Ecosystem Restoration Program (ERP) proposes to address a variety of problems caused by these structures which effect natural processes (e.g., sediment transport), habitats (e.g., riverine and riparian aquatic habitat), and species (e.g., winter-run chinook salmon and steelhead).

For rivers with large dams that block anadromous fish migration, ERPP proposes to improve flow and habitat conditions below these dams. Flow and habitat improvements would enhance salmon and steelhead populations in the lower river reaches. The feasibility of restoring anadromous fish above some of these dams may be considered in the future. Cooperation will be required from local irrigation districts and landowners to rectify these problems.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to reduce the effects of human-made structures on the aquatic ecosystem would involve cooperation and support from other established programs underway to protect and improve conditions for anadromous fish and native resident fishes in the Bay-Delta and its watershed. The recovery plan for the Sacramento/San Joaquin Delta native fishes will be considered in the development of proposed actions (USFWS 1996). CVPIA will implement actions that will reduce adverse effects caused by structures (USFWS 1997). California's Salmon, Steelhead Trout, and Anadromous Fisheries Program Act includes actions to reduce adverse effects of structures (Reynolds et al 1993). The Four Pumps Agreement Program continues to develop projects to reduce effects of structures. Endangered Species Act requirements (biological opinions and habitat conservation plans) will ensure maintenance of existing habitat conditions and implementation of recovery actions (NMFS 1997).

The blockage of migrating anadromous fish in mainstem rivers and tributary streams is a major concern of the Central Valley Project Improvement Act's (CVPIA's) Anadromous Fish Restoration Program (AFRP) and California Department of Fish and Game's (DFG's) Salmon and Steelhead Restoration Program.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Dams and other humanmade structures are found throughout the ERPP Study Area and its ecological management zones. Large water storage and flood control dams are present on the large rivers and streams and many smaller streams. Water storage and diversion structures impair ecological processes such as Central Valley streamflow, natural sediment supply, stream meander, natural floodplain and flood processes, and Central Valley stream temperatures. This group of stressors also impairs a variety of habitats needed to support fish, wildlife, and plant communities. The most adversely affected habitat is riparian and riverine aquatic habitat. Virtually all fish, wildlife and plant community populations which are dependent on seasonal and perennial aquatic habitats have been reduced. This is particularly true for anadromous fish populations which no longer have access to their former oversummering, spawning, and rearing areas above the major dams.

OBJECTIVES, TARGETS, ACTIONS, AND MEASURES

> One Strategic Objective for dams and other structures is to establish hydrologic regimes in regulated streams, including sufficient flow timing, magnitude, duration, and high flow frequency, to maintain channel and sediment conditions supporting the recovery and restoration of native aquatic and riparian species and biotic communities.

LONG-TERM OBJECTIVE: For regulated rivers in the region, establish scientifically based high-flow events necessary to maintain dynamic channel processes, channel complexity, bed sediment quality, and natural riparian habitats where feasible.

SHORT-TERM OBJECTIVE: Through management of the reservoir pool or deliberate reservoir releases, provide a series of experimental high-flow events in regulated rivers to observe flow effects on bed mobility, bed sediment quality, channel migration, invertebrate assemblages, fish abundance, and riparian habitats over a period of years. Use the findings of these studies to reestablish natural stream processes where feasible, including restoration of periodic inundation of remaining undeveloped floodplains.

RATIONALE: Native aquatic and riparian organisms in the Central Valley evolved under a flow regime with pronounced seasonal and year-to-year variability. Frequent (annual or longer term) high flows mobilized gravel beds, drove channel migration, inundated floodplains, maintained sediment quality for native fishes and invertebrates, and maintained complex channel and floodplain habitats. By deliberately releasing such flows from reservoirs, at least some of these physical and ecological functions can probably be recreated. A program of such high-flow releases, in conjunction with natural high-flow events, lends itself well to adaptive management because the flows can easily be adjusted to the level needed to achieve specific objectives. However, it should be recognized that channel adjustments may lag behind hydrologic changes by years or decades, requiring long-term monitoring. Also, on most rivers, reservoirs are not large enough to eliminate extremely large, infrequent events so these will continue to affect channel form at irregular, often long, intervals; artificial high-flow events may be needed to maintain desirable channel configurations created during the natural events.

This objective is similar to the previous one but differs in its focus on flows that are likely to be higher than those needed to maintain most native fish species but that are important for maintaining in-channel and riparian habitats for fish as well as other species (e.g., invertebrates, birds, mammals). Experimental flow releases also will have to be carefully monitored for negative effects, such as encouraging the invasion of unwanted non-native species.

STAGE 1 EXPECTATIONS: Studies should be conducted on five to 10 regulated rivers in the Central Valley to determine the effects of high-flow releases. Natural floodplains should be identified that can be inundated with minimal disruption of human activity. Where positive benefits are shown, flow recommendations should be developed and instituted where feasible.

> Another Strategic Objective is to create and/or maintain flow and temperature regimes in rivers that support the recovery and restoration of native aquatic species.

LONG-TERM OBJECTIVE: Native fish and invertebrate assemblages will be restored to regulated streams where feasible, using methods developed during the short-term objective phase.

SHORT-TERM OBJECTIVE: Provide adequate flows, temperatures, and other conditions to double the number of miles (as of 1998) of regulated streams that are dominated (>75% by numbers and biomass) by assemblages with four or more native fish species.

RATIONALE: Virtually all streams in the region are regulated to some degree, and the regulated flow regimes frequently favor non-native fishes. The native fish assemblages (including those with anadromous fishes) are increasingly uncommon. Recent studies in Putah Creek, the Stanislaus River, and the Tuolumne River demonstrate that native fish assemblages can be restored to sections of streams if flow (and temperature) regimes are manipulated in ways that favor their spawning and survival, usually by having flow regimes that mimic natural patterns in winter and spring but that increase flows during summer and fall months (to make up for loss of upstream summer habitats). Native invertebrates and riparian plants may also respond positively to these flow regimes. Achievement of this objective will require additional systematic manipulations of flows below dams (or the re-regulation of existing flow regimes) to determine the optimal flow and habitat conditions for native organisms, as part of the short-term goal. Part of the studies should be to determine if the objective can be achieved without "new" water, by just altering the timing of releases or by developing conjunctive use agreements that allow more water to flow down the stream channel. Ways to restore native fish communities that do not involve changed flows should be developed (where feasible) to be used in place of or synergistically with changed flows. These findings can then be applied opportunistically to achieve the long-term goal of restoring native fish communities.

STAGE 1 EXPECTATIONS: Surveys will have been completed to determine the status of native fishes in all regulated streams of the Central Valley and flow recommendations made to restore native fishes where feasible. During negotiations for relicensing of dams, agency personnel should request flow regimes favorable for native fishes.

Another Strategic Objective is to restore coarse sediment supplies to sediment-starved rivers downstream of reservoirs to support the restoration and maintenance of functional natural riverine, riparian, and floodplain habitats.

LONG-TERM OBJECTIVE: Implement a comprehensive sediment management plan for the Bay-Delta system that will minimize problems of reservoir sedimentation and sediment starvation, shift aggregate extraction from rivers to alternate sources, and restore continuity of sediment transport through the system to the extent feasible.

SHORT-TERM OBJECTIVE: Develop methods and procedures to end gravel deficits below dams and mining operations; prioritize for correcting existing streams with major deficit problems and initiate action on at least 10 streams.

RATIONALE: One of the major negative effects of dams is the capture of coarse sediments that naturally would pass on to downstream areas. As a result, the downstream reaches can become sediment starved, producing "armoring" of streambeds in many (but not all) rivers to the point where they provide greatly reduced habitat for fish and aquatic organisms and are largely unsuitable for spawning salmon and other anadromous fish.

This objective can be accomplished by a wide variety of means, but most obviously through artificial importation of gravel and sand. Other possible actions include: (1) explore the feasibility of passing sediment through small reservoirs; (2) remove nonessential or low-value dams; (3) eliminate instream gravel mining on channels downstream of reservoirs, and limit extraction on unregulated channels to 50% of estimated bedload supply or less (or to levels determined not to negatively impact fish and other ecological resources); (4) develop incentives to discourage mining of gravel from river channels and adjacent floodplain sites; and (5) develop programs for comprehensive sediment management in each watershed, accounting for sediment trapped by reservoirs, availability of sediment from tributaries down stream of reservoirs, loss of reservoir capacity, release of sediment-starved water downstream, channel incision and related effects, and the need for sources of construction aggregate.

STAGE 1 EXPECTATIONS: Sediment-starved channels in the Bay-Delta system will have been identified; strategies to mitigate sediment starvation, such as shifting mining of gravel from river channels to alternate sources, adding gravel below dams, and removing nonessential dams will have been developed; demonstration projects will have been implemented (and monitored) to mitigate sediment starvation in at least six rivers.

Another Strategic Objective is to re-establish floodplain inundation and channel-floodplain connectivity of sufficient frequency, timing, duration, and magnitude to support the restoration and maintenance of functional natural floodplain, riparian and, riverine habitats.

LONG-TERM OBJECTIVE: Reestablish active inundation of floodplains with area targets and inundation frequencies (1-5 years) to be set for each major alluvial river (where feasible) based on probable pre-1850 floodplain inundation regimes and on existing opportunities to modify existing land uses.

SHORT-TERM OBJECTIVE: Reestablish active inundation of at least half of all remaining un-urbanized floodplains in the Central Valley, where feasible.

RATIONALE: Frequent (often annual) floodplain inundation was an important attribute of the original aquatic systems in the Central Valley and was important for maintaining diverse riverine and riparian habitats. Important interactions between channel and floodplain include overflow onto the floodplain, which (1) reduces the cutting down of the channel, (2) acts as a "pressure relief valve", permitting a larger range of sediment grain sizes to remain on the channel bed, (3) increases the complexity and diversity of instream and riparian habitats, and (4) stores floodwater (thereby decreasing flooding downstream). The floodplain also provides shading, food organisms, and large woody debris to the channel. Floodplain forests serve as filters to improve the quality of water reaching the stream channel by both surface flow and groundwater. The actions necessary to reestablish active inundation will probably require major land purchases or easements, and financial incentives to move existing floodplain uses elsewhere, as has been done in the Midwest since 1993. Obviously, artificial inundation events will have to be planned to take into account other needs for stored water, including increased summer flows.

STAGE 1 EXPECTATIONS: All existing un-urbanized floodplains in the Central Valley will have been identified and a priority list for floodplain restoration projects developed. Strategies for the restoration of natural channel and floodplain dynamics will have been developed and implemented in at least two large demonstration projects. Results of initial floodplain reactivation projects will be used to increase understanding of channel-floodplain interactions and the potential for restoration of processes.

RESTORATION ACTIONS

The general target for dams and other human-made structures is to reduce or eliminate their adverse influence on ecological processes, habitats, and dependent species.

The following actions would help to restore healthy populations of Central Valley fish:

- Upgrade existing ladder systems to improve fish passage where needed.
- Construct fish ladders, where appropriate, to minimize blockages of upstream migrating anadromous fish behind weirs.
- Provide adequate fish passage, including fish ladders and appropriate attraction flows to the ladders, for small- to moderate-sized diversion dams.
- Where feasible and consistent with other uses, reconstruct diversions or remove dams to allow fish passage.

MSCS CONSERVATION MEASURES

The following conservation measures are included in the Multi-Species Conservation Strategy (2000) which provide additional detail to ERP actions that would help achieve species habitat or population targets.

- Coordinate protection, enhancement, and restoration of occupied and historic Central Valley habitats used by listed species with other federal, state, and local programs (e.g., the SB 1086 Program, the Anadromous Fish Restoration Program, U.S. Fish and Wildlife Service recovery plans, and the Corps' Sacramento and San Joaquin River Basins Comprehensive Study) that could affect management of current and historic habitat use areas to avoid potential conflicts among management objectives and identify opportunities for achieving multiple management objectives.

- Implement applicable management measures identified in the restoration plan for the Anadromous Fish Restoration Program and the recovery plan for the native fishes of the Sacramento/San Joaquin Delta.
- Implement management measures identified in the proposed recovery plan for the Sacramento River winter-run chinook salmon.
- To the extent consistent with CALFED objectives, manage operations at the Red Bluff diversion dam to improve fish passage, reduce the level of predation on juvenile fish, and increase fish survival.
- To the extent consistent with CALFED objectives, operate physical barriers in the Delta in a manner to assist in achieving recovery goals.
- To the extent consistent with CALFED objectives, remove diversion dams that block splittail access to lower floodplain river spawning areas.
- Consistent with CALFED objectives, modify operation of the barrier at the Head of Old River to minimize the potential for drawing splittail toward the south Delta pumping plants.
- Consistent with CALFED objectives, modify operation of the Delta Cross Channel to minimize potential to increase exposure of splittail population in the Delta to the south Delta pumping plants.
- Identify and implement measures to eliminate standing of green sturgeon in the Yolo Bypass or to return stranded fish to the Sacramento River.

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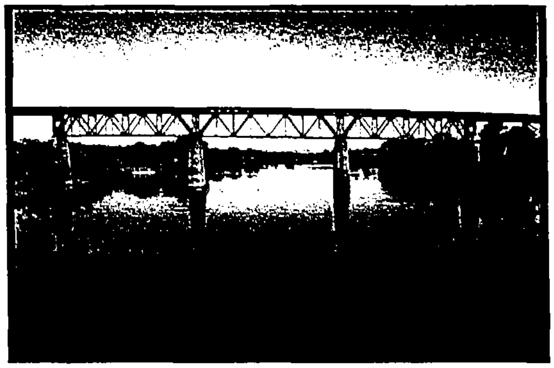
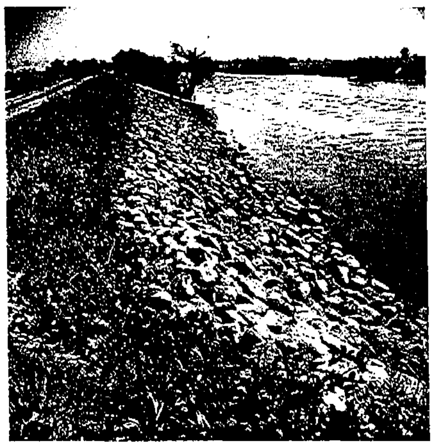
◆ Levees, Bridges, and Bank Protection





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Introduction

Three major bypass systems (Butte Basin Overflow, Yolo Bypass, and Sutter Bypass) and more than 2,000 miles of major levees confine floodflow in the Sacramento-San Joaquin Valley tributaries, rivers, and the Bay-Delta.

Levees, bridges, and bank protection structures inhibit overland flow and erosion and depositional processes that develop and maintain floodplains, and allow stream channels to meander. Levees prevent floodflows from entering historic floodplains behind levees, stopping floodplain evolution, and eliminating or altering the character of floodplain habitats. Confining floodflows to channels also increases the fluvial energy that scours or incises channel beds and reduces or halts channel meander and oxbow formation. Bridges have a similar, though generally more localized effect, on channel morphology and sediment transport.

Factors that relate to the degree of influence levees, bridges, and bank protection have on the Bay-Delta include the location and maintenance requirements of these structures.

Stressor Description

Levees were constructed in the late 19th and early 20th Century to contain the frequent flood flows. Protecting farms, towns, and cities from the devastation of floods drove levee decisions. Another driving force behind levee construction was enhancing river navigation. Thus, levees were placed near riverbanks to increase scour and prevent shoal and bar formation while making the most land available for reclamation. To further improve navigability, a fleet of "snag boats" was employed to remove fallen trees in the channel between the Delta and Red Bluff.

Each section of paired levees, constructed by State and federal projects along major rivers in the valley, is designed to carry a particular flow or flood event. Design flow is determined with the assumption that channel "roughness" (i.e., resistance to flow) will not exceed certain values. Sometimes levees fail even when floodflow is below the maximum design stage, particularly when floodflows have a long duration, such as in January 1997.

Construction materials and standards used to build the early levees would not meet present U.S. Army Corps of Engineers (Corps) structural criteria. Delta levees allowed tidally-influenced emergent marsh to be converted to productive farmland and towns.

In some cases, bank protection has been installed on channelbanks without a levee to protect the landside from erosion inside the river's active floodplain.

In some places, the width of the levees is only a little wider than the width of the channel at low flow, such as along the Sacramento River downstream of Colusa. Restricted channels typically cause deeper, faster velocities during high stage. The amount and width of potential riparian vegetation are restricted by narrow levees, and these river reaches have a low ratio of shallow-water habitats to deep, open water. Cross sections of these channels are typically trapezoidal, rather than a more natural contour with low bank angles and one or more horizontal floodplain surfaces.

Today, most of the Delta levees are higher, steeper, and therefore, pose greater potential risk of failure. This is a result of land subsidence caused primarily by the oxidation, erosion, and depletion of peat soils in the Delta. The former tule islands now resemble steep-sided bowls 5-25 feet below mean sea level.

Extensive areas in San Pablo Bay, Suisun Bay, the Delta, and the Yolo and San Joaquin basins are below mean high tide but are not subject to tidal action because of levees and flapgates. This reduces the area and water volume subject to tidal mixing and reduces the size of the Delta floodplain. Reduced residence time of Delta water and nutrients restricts the development of complex molecules and foodweb organisms. Diked tidelands also may have an artificially high concentration of salt at the surface.

Perimeter Delta floodplains and intertidal zones were formerly punctuated with many miles of low-velocity backwater channels and distributaries. Backwater channels served as nutrient, sediment, and foodweb exchange and delivery systems, as well as important rearing habitat for juvenile fish. At low tides, these branching slough systems provided several miles of mudflat and shallow shoal habitat for shorebirds, wading birds, and waterfowl. Although there are many channels on Delta islands and diked tidelands, they are isolated from the rivers and estuaries by levees. Many have been filled or drained.

Upstream of the Delta, several small and large freshwater tidal sloughs and secondary oxbow channels of the Sacramento and San Joaquin Rivers were once intertwined with main river channels. However, levee construction severed the connections. Some of these former secondary channels are still present as isolated lakes, while others have been filled or drained.

The need for extensive bank protection, primarily rock riprap, has increased because riverbanks have eroded into the narrow floodplains that typically separate levees from channelbanks, highways, railroads, or bridges. In the Delta, riprap is required to protect steep-sided levees from waves caused by wind and boat wakes in wide channels.

Most Delta levees have minimum bank vegetation, and many are covered by rock riprap. Therefore, the riparian corridor is very narrow or absent along Delta channels. In addition, the physical processes necessary to sustain floodplain habitats may be absent or diminished. Riparian vegetation is not allowed to grow on or near most levees further narrowing available habitat area. The aquatic and terrestrial habitat quality of the Delta and river corridor have declined as the percentage of riprapped levee segments increases. Tens of thousands linear feet of riprap are planned for the next phase of the Sacramento River Bank Protection Project.

Bridge spans are often much more narrow than the natural floodplain width, so bridges are usually flood stage "bottlenecks." Backwater effects during high flow may cause channel instability. Additional bank revetment and reduced vegetation are often required so flood flows may safely pass under bridges. At least 31 major bridge crossings exist on the Sacramento River, 10 each across the lower Feather and American Rivers, at least 25 on major Delta sloughs and rivers, and 18 across the lower San Joaquin River to Mossdale.

ISSUES AND OPPORTUNITIES

FLOOD MANAGEMENT AS ECOSYSTEM TOOL: The current approach is to control floods using dams, levees, bypass channels, and channel clearing. This approach is maintenance intensive, and the underlying cause of much of the habitat decline in the Bay-Delta system since 1850. Not only has flood control directly affected ecological resources, but confining flows between closely spaced levees also concentrates flow and increases flood problems downstream. With continued deterioration of flood control infrastructure, further levee failures are likely. Emergency flood repairs are stressful to local communities and resources and often result in degraded habitat conditions. An alternative approach is to manage floods, recognizing that they will occur, they cannot be controlled entirely, and have many ecological benefits. Allowing rivers access to more of their floodplains actually reduces the danger of levee failure because it provides more flood storage and relieves pressure on remaining levees. Valley-wide solutions for comprehensive flood management are essential to ensure public safety and to restore natural, ecological functioning of river channels and floodplains. Integrating ecosystem restoration with the Army Corps of Engineers' Comprehensive Study of Central Valley flood management can help redesign flood control infrastructure to accommodate more capacity for habitat while reducing the risks of flood damage (Strategic Plan 2000).

OPPORTUNITIES: Coordinate with the various levee and flood control state, local, and federal programs to establish design criteria and standards that ensure that levee rehabilitation projects incorporate features beneficial to the aquatic and riparian environments of the Delta. The majority of the approximately 50 Delta islands are hydrologically disconnected by levees from the primary channel, open-water estuarine environment. Most of these levees are likely to remain in future years and to be reinforced with rock riprap, raised and widened, or rehabilitated in other ways to prevent levee failure. Potentially beneficial projects that could be incorporated into these programs include levee setbacks and creation of broad submerged benches, as well as the construction of broader levees to support riparian vegetation. Developing contingency plans for responses to major and multiple levee failures in different parts of the Delta can also provide ecosystem benefits and minimize disturbances associated with levee repair (Strategic Plan 2000).

Mimic natural flows of sediment and large woody debris. Dams disrupt the continuity of sediment and organic-debris transport through rivers, with consequent loss of habitat, and commonly, river incision, downstream. In some cases, such as Englebright Dam on the Yuba River, the feasibility of dam removal should be evaluated as a sustainable solution to reestablishing continuity of sediment and debris transport, as well as providing access to important spawning and rearing areas. Most dams, however, cannot be removed, so methods must be sought to reestablish continuity of sediment and wood transport with the dam in place. Coarse sediment can be artificially added below dams to at least partially mitigate for sediment trapping by the dam and ameliorate the impacts of sediment-starved flows. This approach has been successfully used in Europe, using sediment from natural (landslide) and artificial sources (injected from barges). On the River Rhine, enough gravel and sand are added below the lowest dam to satisfy the present sediment transport capacity of the Rhine to prevent further incision of the bed (an average of over 200,000 cubic yards annually). On the Sacramento River, gravels have been added at a rate much below the river's transport capacity so they are vulnerable to washout at high flows. A more sustainable approach would be to add gravel (and sand) on a regular basis and at a much larger scale to better mimic natural sediment loads and therefore provide the sediment from which the river would naturally create and maintain spawning riffles. This latter approach requires a large commitment of resources and should be undertaken only in rivers where other factors (e.g., temperature regime) are favorable (or can be made favorable) for recovery of species (such as the upper Sacramento). Such opportunities will be more economical where sources of dredger tailings or reservoir Delta deposits are available nearby.

While recognizing the navigation and flood safety issues associated with large woody debris in rivers, the importance of this debris to the foodweb and structural habitat for fish should not be overlooked. There is an opportunity to investigate ways by which to pass debris safely through dams and bridges. This may require replacing some existing bridges with those less prone to trapping woody debris (Strategic Plan 2000).

VISION

The vision for levees, bridges, and bank protection is to reduce the adverse effects of these structures in order to improve riverine and floodplain habitat conditions to assist in the recovery of State- and federally listed fish species, and other fish and wildlife.

Depending on size, location, and type of habitat, setback levees can be used to create high-quality habitat nodes along low-quality, narrow sections of leveed rivers and streams. Much of the interior of central and west Delta islands are at an elevation too low for extensive levee setbacks to be feasible or desirable but should be evaluated on a case-by-case basis. Setback levees may be feasible in the east, north, and south in perimeter Delta areas, Levees set back to higher, firmer ground are more reliable and the setback zone may be available for restored habitats, or farmed part of the year.

In some cases, levees can simply be breached or removed so that the floodplain is setback to the natural shoreline. The soil could be used for restoration elsewhere. Breached-levee areas are prime candidates for restoring networks of small tidal sloughs and shallow backwater channels, increasing habitat complexity and diversity.

Some Delta islands pose overwhelming constraints to agricultural practices and levee and drainage-pump upkeep. Some are candidates for conversion to aquatic and tidal emergent wetland habitats. The Ecosystem Restoration Program Plan recommends a subsidence-control program to gradually restore island elevations.

Actions to control subsidence include:

- managing nontidal emergent and seasonal wetlands to accrete organic island soils.
- filling or raising with clean dredge materials, crop stubble, and soil material, excavated to expand floodway capacity.

Reflooded Delta islands would create a mosaic of interfaced habitat types. Depending on fill available material and island elevations, created habitats should include deep, open-water (greater than 6 feet below mean sea level), shallow-aquatic and nearshore habitats; intertidal mudflats and tule marsh; willow scrub; and mixed riparian forest. Saline areas also support halophytic plant communities such as saltgrass and pickleweed.

Several pilot projects to expand shallow, nearshore habitats along Delta channels using low benches along levees have been constructed and monitored in recent years. These designs will be refined and their application expanded. Other areas of the Delta that have more-than-adequate floodflow capacity could support more vegetation and fill in the channel. Because of the limited width of the area restored and high installation costs of this approach, this measure is considered a lower priority to levee setbacks and removal projects.

Integration with Other Restoration Programs

Efforts to reduce the impacts of levees, bank protection, and bridges will involve coordination with other programs. These include:

- the Upper Sacramento River Fisheries and Riparian Habitat Advisory Council (SB1086) group efforts to limit the placement of rock on banks of the river, and other river corridor management plans;
- the Corps' proposed reevaluation of the Sacramento River Flood Control Project and ongoing Bank Protection Project, including more comprehensive floodplain management and river ecosystem restoration opportunities;
- wetland restoration, under the Delta Flood Protection Act (AB360), such as Decker Island and Sherman Island habitat projects;
- proposed riparian habitat restoration and floodplain management studies, including potential new flood bypass systems and expanded river floodplains on lands recently acquired by the California Department of Parks and Recreation and U.S. Fish and Wildlife Service;
- planned and proposed restoration of diked tidelands of Suisun Marsh and San Pablo Bay and islands in the south Yolo Bypass and Delta; and
- several studies and pilot demonstration projects by the Corps, California Department of Fish and Game, California Department of Water Resources, and others to develop new alternative designs for bank revetment or biotechnical levee protection along rivers and in the Delta that allow for shoreline riparian, marsh, and shallow aquatic habitats.

Linkage with Other Ecosystem Elements

Levees, bridges and bank protection adversely affect important ecological processes, habitats, and species in the ERPP Study Area. For example, bank protection limits stream channel meander, erosion, reduces opportunity for sediment deposition, and restricts opportunity to regenerate riparian and riverine aquatic habitats. In turn, fish, wildlife, and plant communities are restricted or imperiled.

OBJECTIVE, TARGETS, ACTIONS, AND MEASURES

> The Strategic Objective for levees, bridges, and bank protection is to reestablish floodplain inundation and channel-floodplain connectivity of sufficient frequency, timing, duration, and magnitude to support the restoration and maintenance of functional natural floodplain, riparian, and riverine habitats.

LONG-TERM OBJECTIVE: Reestablish active inundation of floodplains with area targets and inundation frequencies (1-5 years) to be set for each major alluvial river (where feasible) based on probable pre-1850 floodplain inundation regimes and on existing opportunities to modify existing land uses.

SHORT-TERM OBJECTIVE: Reestablish active inundation of at least half of all remaining unurbanized floodplains in the Central Valley, where feasible.

RATIONALE: Frequent (often annual) floodplain inundation was an important attribute of the original aquatic systems in the Central Valley and was important for maintaining diverse riverine and riparian habitats. Important interactions between channel and floodplain include overflow onto the floodplain, which (1) reduces the cutting down of the channel, (2) acts as a "pressure relief valve", permitting a larger range of sediment grain sizes to remain on the channel bed, (3) increases the complexity and diversity of instream and riparian habitats, and (4) stores floodwater (thereby decreasing flooding downstream). The floodplain also provides shading, food organisms, and large woody debris to the channel. Floodplain forests serve as filters to improve the quality of water reaching the stream channel by both surface flow and groundwater. The actions necessary to reestablish active inundation will probably require major land purchases or easements, and financial incentives to move existing floodplain uses elsewhere, as has been done in the Midwest since 1993. Obviously, artificial inundation events will have to be planned to take into account other needs for stored water, including increased summer flows.

STAGE 1 EXPECTATIONS: All existing unurbanized floodplains in the Central Valley will have been identified and a priority list for floodplain restoration projects developed. Strategies for the restoration of natural channel and floodplain dynamics will have been developed and implemented in at least two large demonstration projects. Results of initial floodplain reactivation projects will be used to increase understanding of channel-floodplain interactions and the potential for restoration of processes.

RESTORATION ACTIONS

The general target for levees, bridges, and bank protection is to reduce or eliminate adverse effects on ecological processes, habitats, and dependent species to the extent possible, and in a manner consistent with flood control.

Actions to reduce adverse effects of levees, bridges, and bank protection on the Bay-Delta ecosystem would include the following:

- Investigate the feasibility of levee setbacks along rivers.
- Investigate the feasibility of levee setbacks in the Delta.
- Convert selected Delta islands to a mosaic of deep- and shallow-water and tule-marsh habitats.
- Build innovative benches to support shoreline habitats, where levees must remain.
- Tier from on-going programs to contribute to successful implementation.

MSCS CONSERVATION MEASURES

The following conservation measures were included in the Multi-Species Conservation Strategy (2000) to provide additional detail to ERP actions that would help achieve species habitat or population targets.

- Coordinate protection, enhancement, and restoration of occupied and historic Central